RL-TR-95-247
In-House Report
November 1995

DISTRIBUTED VIDEO SENSORS PROVIDE AUTOMATED SURVEILLANCE OF TRAFFIC FLOW ON THE LONG ISLAND EXPRESSWAY

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RL-TR-95- 247 has been reviewed and is approved for publication.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1995	In-House 10 Jun 95-15 Aug 95

4. TITLE AND SUBTITLE
DISTRIBUTED VIDEO SENSORS PROVIDE AUTOMATED SURVEILLANCE OF TRAFFIC FLOW ON THE LONG ISLAND EXPRESSWAY

5. FUNDING NUMBERS
PE - 920H
PR - R507
TA - 01
WU - 01

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER
RL-TR-95-247

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Rome Laboratory (C3BB)
525 Brooks Road
Rome, New York 13441-4505

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
N/A

11. SUPPLEMENTARY NOTES
Rome Laboratory Project Engineer: Scott S. Shyne/C3BB (315)330-4819

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
Advanced Traffic Management Systems (ATMS) are designed to provide real time traffic monitoring, situation assessment, and response capability to the traffic engineer. In an urban freeway environment, incident management is one of the most critical and effective elements of an ATMS system. Incident management involves the rapid detection, confirmation and response to incidents such as vehicle accidents and breakdowns. This paper discusses the Traffic Flow Visualization and Control (TFVC) System under development for implementation on the Long Island Expressway in New York. The purpose of this system is to significantly improve the incident management capability for the New York State Department of Transportation (NYSDOT).

14. SUBJECT TERMS
Video Surveillance Sensing, Neural Networks Distributed Processing

15. NUMBER OF PAGES
36

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	U/L

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2.89)
Prescribed by ANSI Std. Z39-18
298-102

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1.0 INTRODUCTION

The need to improve the flow of traffic on overcrowded highways is obvious to any motorist in major metropolitan areas. Traffic congestion contributes to unacceptable delays, increased emissions from idling cars, motorist frustration, and an overall increase in traffic incidents. The conventional solution of "building more roads" is in many cases an inefficient remedy given the rising construction costs, limited available space, and the intrusive affects of interrupting traffic flow for roadway modifications. In response to these concerns, there has been a national focus to develop Intelligent Transportation Systems (ITS) that creatively utilize state-of-the-art information and device technology to improve the flow of traffic.

The Advanced Traffic Management System (ATMS), a component of ITS, provides real-time traffic monitoring capability and accurate situation assessment information to the traffic control engineer. The primary focus of this report will be to discuss one embodiment of ATMS, the Traffic Flow Visualization and Control (TFVC) system, as implemented on I-495, the Long Island Expressway (LIE) in New York.

The New York State Department of Transportation (NYSDOT), Federal Highway Administration, Rome Laboratory and Kaman Sciences Corporation have joined forces to develop an automated, video based surveillance and detection system to monitor the flow of traffic on a multi-lane highway system. The initial operational fielding of the system occurred on the Long Island Expressway (LIE) in New York during the summer of 1995. The Traffic Flow Visualization and Control (TFVC) system utilizes a distributed sensor architecture that provides automated

sensing of traffic flow on the LIE while also providing a real-time video surveillance capability.

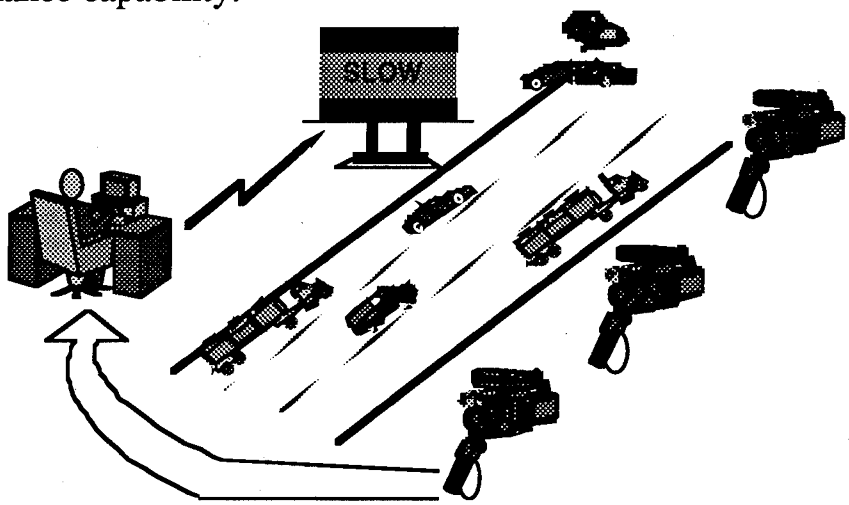

FIGURE 1 - CONCEPT DIAGRAM OF TFVC SYSTEM

The TFVC system provides a revolutionary approach to traffic monitoring. The system has the capability to extract only the relevant traffic data from images generated from conventional cameras, then format essential data for further analysis. Video information is gathered at the remote sensor and then forwarded to the central controller. This real-time information update allows the traffic engineer to maintain an updated picture of the traffic situation. Data received at the central controller is displayed using a Graphical User Interface (GUI) where innovative symbolic representations of current and historical traffic data are displayed for easy visualization of traffic conditions. The TFVC system is compatible with many currently existing surveillance camera systems thereby facilitating a low cost retrofittable implementation of ITS. The TFVC system can provide an operational capability for traffic monitoring by utilizing any type of communications media; the more bandwidth available, the higher the frame rate of the video display. The TFVC

system is also a non-intrusive sensor that does not require digging or excessive construction to install.

A technique known as Wide Area Video Surveillance (WAVS) is being exploited to capture the maximum amount of situational information from the video data. This technique analyzes the entire traffic flow scene and identifies key areas of interest for detailed analysis. As individual frames from the video camera are analyzed, image exploitation algorithms identify key discriminating elements of the traffic scene and capture the information to be transmitted in an encapsulated format to the traffic operations center. Previous technologies used for vehicle information data collection have been point sensing systems. A point sensing system consists of many individual sensors that act as unique "stimulation" points for the collection of data. As one sensor is activated by some form of stimuli, information is collected from the stimuli and fed back to a central collection point in the overall system. All of these "points" of data can then be connected together to form a pattern of activity. These types of systems have been in existence for many years. Inductive loop detectors are the most commonly used point sensing vehicle data collection devices. Recent improvements in video detection technology led to the development of Autoscope, which uses a point sensing approach to video surveillance detection. With Autoscope, a small section of the highway is selected as the "sensing" point. When the vehicle passes over that section, specific vehicle information such as count and speed is collected. These individual pieces of data can be reconstructed into a scenario map that displays an interpretive representation of the current traffic conditions. Unfortunately, by only analyzing individual points of data, other relevant information may be missed. If an important piece of information falls

outside of the specific sensing area, it cannot be utilized to correctly reflect the current traffic situation. The use of WAVS greatly increases the probability of incident detection and will significantly affect the overall confidence factor associated with making critical traffic engineering decisions to rectify undesirable traffic situations.

This report will outline the technical aspects of the System Architecture. It will also illustrate the Iterative Design Approach utilized in the program as a means of providing early capability demonstrations and continuously improving the design based on operational testing experience. Major milestones in the systems development process include a Non Real Time System (NRT), Fast Track (FT) system, the Laboratory System (LS), and a Prototype System (PS) that will demonstrate the full system capabilities. Results and lessons learned from the initial testing of the Fast Track system on I-495 will be discussed. A section on future expansion for the TFVC system will explore potential development of intelligent video sensors for arterial access, intersection control, portable construction surveillance, and a multi-sensor fusion detection system.

2.0 ITERATIVE DESIGN APPROACH

The development of the TFVC system requires a design approach that facilitates a continual enhancement of the system at each step of the design process, adding further capability and functionality. The system would also benefit from a design process that permits continual review of the system for constant improvement and early functionality testing, while minimizing associated risks. The Iterative Design Approach (IDA) represents the ideal process to best satisfy these requirements. The basic

concept of IDA is a cyclic development approach where requirements are determined and a design is created, implemented, and tested.

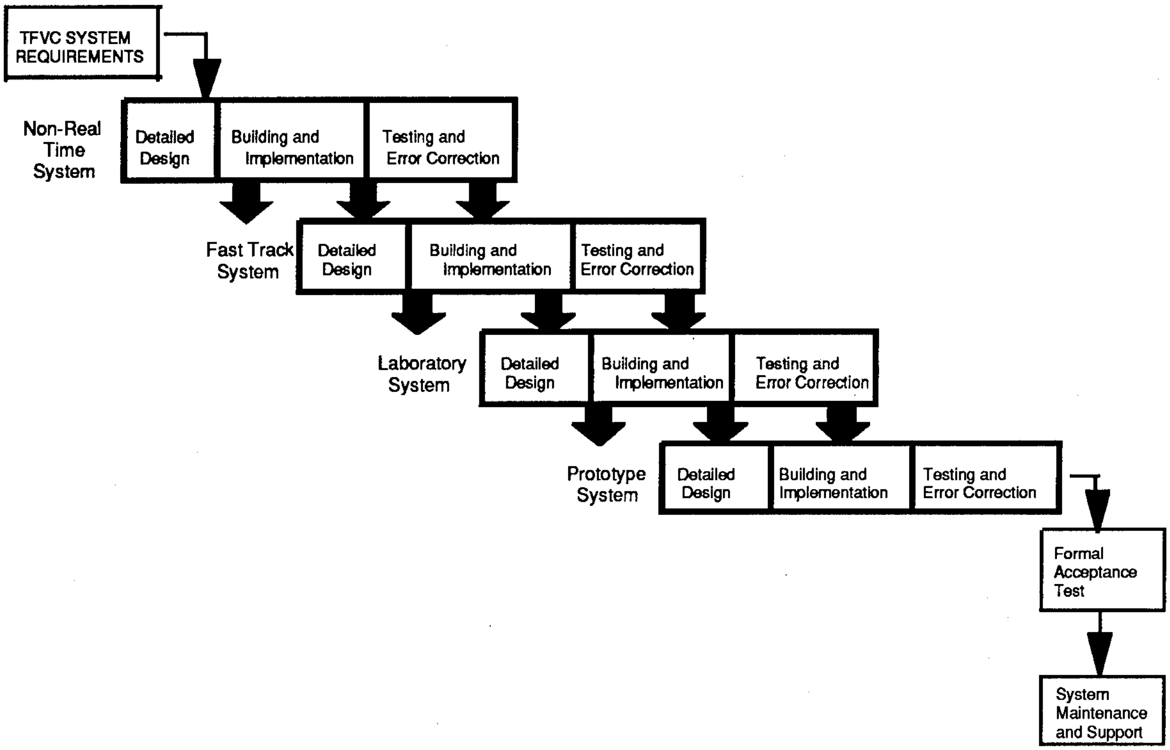

FIGURE 2 - ITERATIVE DESIGN APPROACH

Any errors in the design can be detected and corrected during the early stages of system development. Using this proven system as a base, a building block approach is applied where further capability is designed and implemented into the already existing system. Additional testing is performed on the new system where errors are once again detected and corrected. This cycle may continue through several iterative design stages, where at each step, the functional capability increases through a systematic enhancement process. The IDA also provides for a methodical investigation into the causes and sources of errors, thereby facilitating easy revision and correction according to insights gained between steps. Because testing occurs frequently (at the end of each cycle), the system allows for backtracking, rework, improvement, and feedback on a regular

basis, which ultimately adds to the quality of the system. Potential hidden problems are identified, which allows for better future planning, and minimizes the risk to each component of the design. Additionally, with this approach there is a greater focus on understanding the dependencies that exist in the system as well as further investigation into discoveries made during the design that may raise further points for analysis. Fundamentally, the IDA provides the customer with early insight into the overall functionality of the system by producing tangible results at critical milestones during the development cycle through the use of early capability demonstrations. Each step of the design process further refines and enhances the system thereby producing a higher quality, more reliable product. (1,2,3, 4)

The first of the four principal stages of the IDA for the TFVC system is the Non-Real Time (NRT) system. The NRT test environment serves as the initial development platform for testing algorithms. The algorithms for flow speed, automatic lane definition, individual vehicle speed, vehicle separation, and gross vehicle classification are designed and tested on the NRT using video tapes of highway traffic from I-495 in Long Island and I-25 in Colorado Springs. The NRT serves as a site for integration, testing, and characterization of basic system functions. Problems can easily be identified and corrected before further risk is taken. This development strategy also allows the user to see a preliminary version of the system that demonstrates tangible evidence of the unique capability of the TFVC system.

The second stage of the IDA for the TFVC system is the Fast Track (FT) system development. The FT stage allows the development team to gain operational experience by utilizing the FT to automatically monitor

real time traffic flow on I-495, the eventual fielding site. This approach significantly reduces the overall risk to the program by permitting testing in the initial development stages and also gathering user feedback early in the cycle. Essentially, the lab system is packaged for field deployment and installed on I-495 in a five sensor configuration with communication links to the Traffic Operations Center (TOC) and the Central Controller hardware. The FT is tested using two different communications infrastructures, thereby demonstrating the flexibility of the system to utilize virtually any communications media. Originally, the system was linked through Plain Old Telephone Service (POTS) that provided an operational capability for automatic data collection but was limited to one snapshot of the visual scene every two seconds. An upgrade to the Communications subsystem allowed the use of Integrated Switching Digital Network (ISDN) lines, thereby increasing the video update to a rate of ten to fifteen frames per second. It is important to understand that the FT is a very early stage in the overall TFVC system's development process. While the form factor of the FT is very close to the eventual prototype, the FT maintains only a "bare bones" capability for automated traffic monitoring. The basic operation of the FT involves collecting the flow speed data at the remote sensor and sending it to the Traffic Operations Center (TOC) where the Central Controller further processes the traffic information. The data is displayed through the use of traffic visualization diagrams on the Graphic User Interface (GUI). The visualization diagram is a unique way of displaying traffic data in a clear, concise, and user friendly manner. The FT supplies access to historical data (past average flow speeds on a certain date or at a certain time), as well as information about the sensor temperature and acquisition status. The FT also allows the operator to

directly control and configure the remote sensor, including the pan, tilt, focus, zoom, and iris. The remote sensors on I-495 provide a real time testbed to evaluate new algorithms and other system upgrades before the development of the Laboratory System (LS). Some of the remote sensors will return to Colorado Springs, providing in-house development platforms to bridge the transition from the FT to the LS stage of the program.

The third distinct stage of the IDA for the TFVC system is the completion of the Laboratory System (LS). During this stage, the remaining system capabilities are developed and integrated into the TFVC system. The LS is comprised of five full capability sensors that will provide a realistic development test of the final system. This includes additional algorithms that have been designed and implemented since the completion of the FT, including individual vehicle speed, vehicle count, vehicle separation, and gross vehicle classification. The TFVC system will be tested in real time in Colorado Springs to demonstrate it's operational capabilities for both surveillance and detection. At this time there may also be improvements made to the hardware configuration to reduce size and increase reliability due to temperature fluctuation. Other modifications may include upgrading the frame grabber from black and white to high resolution color. Another potential improvement may be to incorporate a Digital Signal Processor (DSP) into the system thus making additional processing power available to handle more complex signal processing requirements generated by algorithms such as the Neural Network (NN) classification of vehicles. The incident detection software will be made more robust in an attempt to identify dangerous situations when these exist on the highway. One example of a potential improvement in this software is the ability to recognize a vehicle traveling in the wrong direction on the

expressway. This potentially dangerous situation can be identified through the interpretation of a negative flow speed registering at the remote sensor. An alarm would sound at the Central Controller so that the traffic engineer can take appropriate action. Basically, the LS serves as a platform for testing and demonstrating the capabilities of the final prototype system.

The prototype system is the final stage of the IDA and represents the end result of the TFVC system development. The system will include 25 sensors that will be installed on I-495 and possess all the capabilities of the LS only on a larger implementation scale. The system will perform both the monitoring function for surveillance and detection purposes as well as the predictive analysis function to determine when dangerous traffic conditions are present. The finished GUI shall provide the traffic engineer with current traffic information in addition to access to the historical database created by archiving past traffic information. The current traffic flow speed will be displayed at the GUI in conjunction with the appropriate historical data (the flow speed at the same time, same day of the week, etc.) so that comparison can provide useful information. As an example: a flow speed significantly lower than the historical average may lead to the conclusion that congestion is present, and control measures should be taken. Likewise, a flow speed above the historical average may lead to the inference that an accident may occur, depending on the weather, traffic patterns, etc. This tool allows an operator to judge if traffic flow is normal or abnormal and if measures should be taken to guide the flow. The visual real time traffic updates and the roadway maps also supplied at the GUI will provide the operator with further surveillance capabilities. Accidents or other unusual traffic situations can be detected automatically. The traffic engineer can then zero in on a specific segment of the highway

to assess the situation quickly and efficiently dispatch emergency assistance if necessary. Further predictive analysis can be performed based on additional historic traffic data. Weather conditions, road conditions, time of day, date (holiday periods vs. non holiday periods), erratic traffic behavior, and other such factors are considered in determination of the probability an accident will occur within an associated confidence interval.

3.0 SYSTEMS ARCHITECTURE

The architecture of the TFVC system is modular by nature so that the system can easily be upgraded over time. Existing video traffic surveillance systems can be retrofitted with the TFVC system without major engineering changes. From a technology perspective, specific hardware components can be upgraded with more advanced modules as the technology progresses. This concept of planning for modular upgrade of system components is known as Pre-Planned Product Improvement or P3I. This system has a flexible architecture to accommodate several different fielding configurations. The TFVC system exploits the distributed approach to information processing which allows the system to provide real time operation with minimal bandwidth requirements within the communications infrastructure. The system processes some of the data at the camera and sends a reduced data set to the central controller where additional processing and deductive reasoning are accomplished. Subsystem module communication is significantly reduced by partitioning the data processing task at the remote sensor and the central controller. Through the minimization of information passed between modules, the system does not require high capacity communications lines to operate. The only function that is significantly affected by a reduced capability

communications subsystem is the video rate. The higher capacity the communications lines, the higher the frame rate for the video. If fiber optic cable is in place, the frame rate can easily be thirty frames per second. With ISDN lines, the frame rate is approximately ten to fifteen frames per second. When POTS is used, without compression or background image subtraction, the frame rate is limited to approximately one frame every two seconds.

The three major architectural components of the TFVC system are the Remote Sensor, the Communications Infrastructure, and the Central Controller.

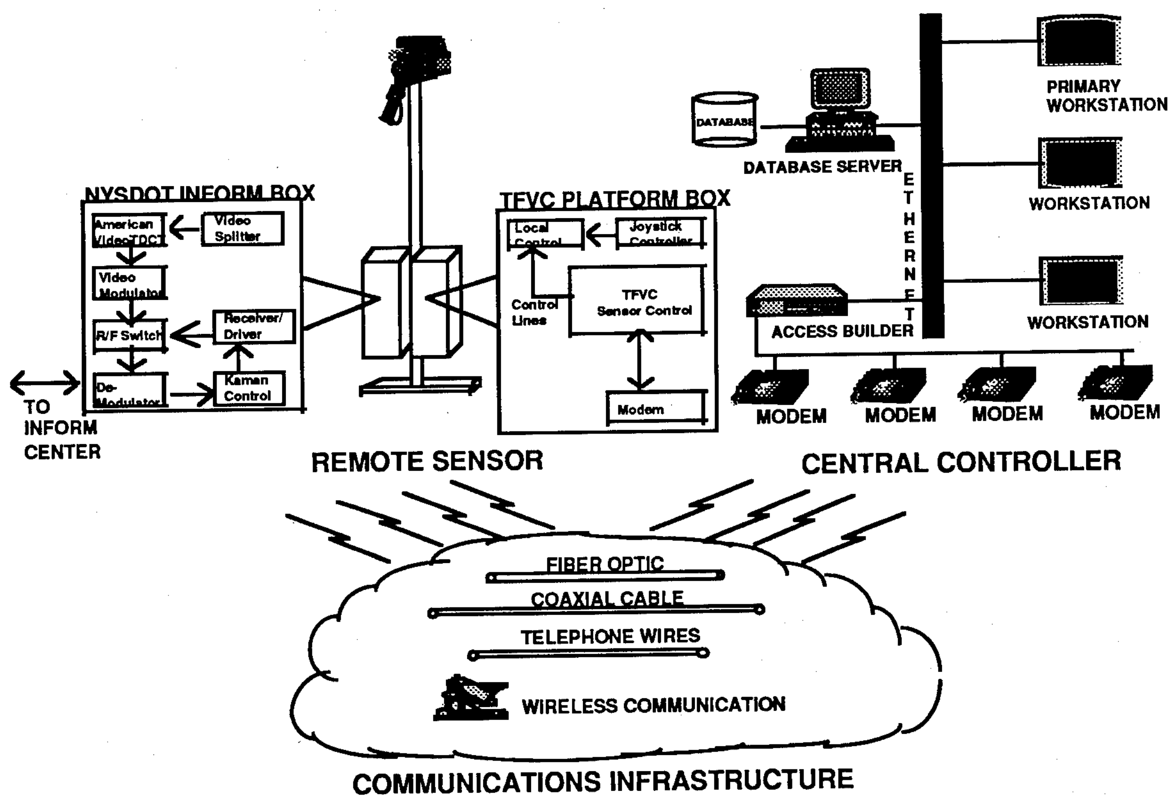

FIGURE 3 - SYSTEMS ARCHITECTURE

3.1 Remote Sensor

The remote sensor platform portion of the TFVC system is in place on the roadside of the Long Island Expressway. The sensor configuration consists of a platform, camera subsystem, Video Data Processor (VDP) and communications/control assets.

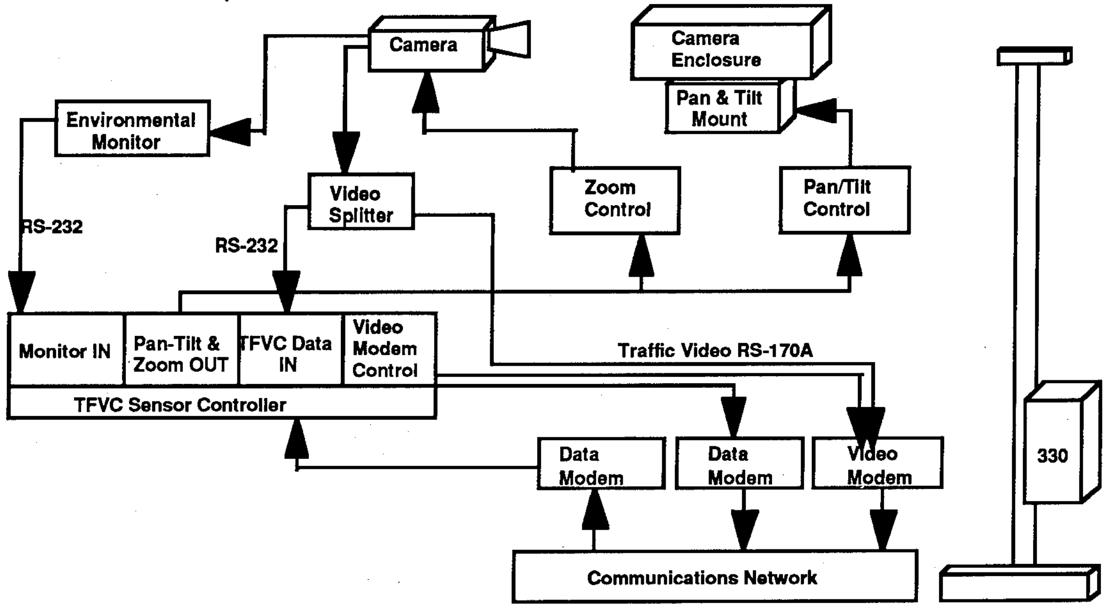

FIGURE 4 - REMOTE SENSOR

The platform is comprised of a concrete base with a thirty foot metal pole. Power and communications lines are connected through the base of the pole. The camera system is mounted on top of the pole and is controlled remotely by an operator at the Traffic Operations Center (TOC). Pan, tilt, zoom, and iris can all be controlled from the TOC through the hardware controllers present at the remote sensor. The camera system consists of a conventional camera and Commercial Off The Shelf (COTS) controllers currently utilized by NYSDOT. This allows NYSDOT to utilize existing logistics support trails to maintain the TFVC system given that the cameras and controllers are directly from DOT inventories. At the base of the pole, there are two model 330 enclosures. One of the cabinets contains the VDP and the other houses the

communications/control assets. It is envisioned that all assets will fit into one cabinet in a final fielding configuration. The VDP is the intelligent processing portion of the remote sensor. A frame grabber board captures individual frames of video data. A Pentium based processor board runs the image exploitation algorithms to extract flow speed, vehicle separation, vehicle classification, and vehicle count. This information is sent to the TOC via the communications network.

3.2 Communications Infrastructure

The modular design of the overall architecture provides the system designer with the flexibility to choose an optimal communications infrastructure depending on the unique implementation requirements. If there are no communications in place and the TFVC system needs to be set up quickly, cellular or wireless assets can be utilized to provide a link that can handle basic flow speed and environmental data. If an existing infrastructure of coaxial cable is in place, all of the data parameters and live video can be sent to the central controller provided a channel can be dedicated to real-time video. A trade off study was completed to determine the pros and cons involved in utilizing various communications infrastructures for the TFVC system. Three options were explored in detail in an attempt to better understand the programmatic and technical effects of utilizing different infrastructures.

The first option involved the use of the existing infrastructure for the INformation FOR Motorists (INFORM) system. INFORM uses RF Coax based communications and an RF trunk network to connect all the INFORM assets. The maximum data rate for the data communications is 1200 baud. This is sufficient for control and encapsulated traffic

information such as average flow speed and vehicle classification. This system can accommodate live video but only for four video sensors at a time, given that their are only four RF modulation channels wide enough to accommodate video. For additional sensors to be put in place, the RF Trunk line would need to be extended which may not solve the expansion problem. The channel bandwidth is fairly stretched to the limit supporting the current inductive loop detector data load of approximately 2000 sensors.

The second option involved utilizing leased telephone lines with high speed data modems. This approach is attractive for several different reasons. First of all, installing phone lines is a straight forward and inexpensive process that the phone company can do practically anywhere. Installation can be accomplished in a relatively short amount of time. The system can support an unlimited number of sensors given that one phone line must be added for every remote sensor. The modems utilized are relatively low cost COTS equipment and are short lead items so they are readily available. The data rate for regular phone lines and high speed modems can be up to 28.8K baud per second. This is more than sufficient for all the data transfer required but still does not provide a live video capability. Through image compression and background subtraction it may be possible to achieve one to three frames per second. An additional expansion to the leased line concept would incorporate ISDN lines, which are more expensive to lease and implement, but guarantee a 128K baud per second rate. These types of lines would sufficiently handle all data communications and provide approximately ten to fifteen frames per second of live video.

The third option that was examined involved a hybrid approach that utilized INFORM RF coax lines for video surveillance and leased phone lines for the encapsulated data transfer. This approach provided a live video capability of thirty frames per second. The number of sensors was unlimited with respect to the data capability, given that each sensor would be connected via phone lines. However, video capability would still be limited to four sensors per trunk line. The cost of utilizing the complex RF modems for each sensor would significantly increase the overall sensor platform cost while not accomplishing the goal of real-time video surveillance from any sensor at anytime.

During the implementation of the Fast Track system, option two was utilized and provided excellent success in terms of capability, ease of implementation, and affordability. The optimal network configuration, from a throughput point of view, would be a fiber optic based approach. Unfortunately, this type of infrastructure can be costly and requires a significant amount of time to put in place. The final communications infrastructure is not currently known but options are continuing to be studied and reviewed. The final communications architecture to be utilized will be selected by the early summer of 1996. The flexibility of the TFVC system design allows for any communications infrastructure to be put in place.

3.3 Central Controller

The Central Controller (CC) for the TFVC system is the primary point of operational control. The CC resides in the INFORM traffic operations center in Hauppauge Long Island and can be operated from the console of the primary workstation. The subsystems that make up the CC

include: remote sensor control, Graphic User Interface (GUI) for display and control, historical database, and a unique communications infrastructure.

The remote sensor control portion of the CC is a mouse driven control panel that allows the user to access a remote sensor location and control the operation of the camera. From the CC, the user can manipulate the pan and tilt of the camera to change the view of the highway. Once the operator has concluded the surveillance of the area, a preset is activated to return the camera to its original position and orientation. Other controls that can be adjusted on the camera from the CC include zoom and iris control. The zoom function allows the user to zero in on any particular point of interest and then hit the preset to bring the lens back to the original configuration. The iris control is important because it allows the operator to control the amount of light that is being let in through the camera lens. This control permits more light to be let in during dawn and dusk operation and less light to be let in under high intensity glare conditions.

The GUI portion of the CC provides several important control and monitoring capabilities. The initial screen of the GUI displays a map of Long Island with areas of remote sensors on the LIE identified by small colored dots. During normal operation the dots are colored green, showing that all conditions are normal. When traffic begins to behave in any irregular fashion, the dots change color to yellow, reflecting a marginal anomaly in traffic flow or flashing red for an incident alert. By selecting the flashing sensor with the cursor, individual sensor information can be brought up on the screen. Visualization diagrams representing flow speed are displayed for each individual sensor platform selected for

monitoring. A historical visualization diagram shows the flow speed over the last 24 hours while at the same time a diagram shows the flow speed over the last few minutes. By selecting the "video" option on the remote sensor GUI window, a new window will open up on the screen with the actual real time video of the flow of traffic.

A historical database is maintained by the CC for the purposes of developing a better understanding of the overall traffic flow of the entire highway system. The remote sensors will create, archive, and transmit traffic observation records. These include the sensor ID and a time stamp for the average flow speed, vehicle count, classification, vehicle separation, and environmental conditions. With a large historical database of traffic information, prediction algorithms can begin to predict times and places where accidents may occur based on previous traffic conditions that resulted in accidents. For the Fast Track system, Microsoft ACCESS will be used to maintain the data. However, this data can easily be spun into a more powerful client-server type program such as ORACLE or Microsoft SQL.

The communications infrastructure for the CC is primarily IEEE 802.3 Ethernet compliant. This Ethernet backbone connects the primary workstation with secondary display workstations and the data base storage units. The high speed data modems are connected to the remote sensors via phone lines. The information that comes into the modems is then converted to TCP/IP packets by a Wide Area Network (WAN) Remote Access Multiplexor and sent over the ethernet to the primary workstation for processing.

4.0 FAST TRACK DEPLOYMENT

The fast track deployment was initiated in June of 1995 as an exercise to gain operational experience with the TFVC sensor. The ability to perform an early fielding exercise significantly reduces the overall program risk because of the opportunity to identify potentially critical failure points early in system's development. A five sensor configuration was installed along a ten mile segment of the Long Island Expressway between Exits 53 and 60. Six major functions were implemented as part of that effort:

- System Communications over POTS and ISDN
- Calculation of continuous traffic flow speed data
- Real time update of flow speed chart
- Access to historical data (flow speed)
- Sensor health and status (temperature and acquisition status) updates
- Testing of lane definition algorithm
- Threshold based incident detection algorithms

Two different communications links were used in an effort to demonstrate system flexibility. Originally, the system was linked through Plain Old Telephone Service (POTS) that provided an operational capability for automatic data collection and a digital video display rate of one frame per second. The use of Integrated Switching Digital Network (ISDN) lines, increased the video rate to greater than six frames per second. The flow speed algorithms were initially calibrated using a radar gun. Additional flow speed data was taken and compared with speed data taken during the same time and location using the radar gun. The radar gun is calibrated using a tuning fork to an accuracy of 0.1 mile/hour.

Conclusion of the FT deployment demonstrated:

- Real time updating of flow speed charts
- Automatic lane definition algorithms operationally tested
- Health and status of remote sensors automatically updated to CC
- Historical flow speed data recorded and archived in database
- Flow speed thresholds work as a basis for incident detection

The FT program will remain in place for at least six months to serve as an operational testing ground for future algorithm development and software updating.

5.0 FUTURE EXPANSIONS BEYOND INITIAL PROGRAM

The technology developed for the TFVC system can be applied to many transportation problems. WAVS technology can be applied to any environment where information can be detected and extracted from a visual scene.

5.1 Arterial Access

Arterial access is an application that would lend itself well to a visual sensor control mechanism. As traffic approaches on a ramp, the visual sensor can detect the incoming flow and coordinate the merging on the expressway. The arterial access application would require a real time adaptive system where the video sensor would collect the data and an intelligent processor would utilize logical reasoning techniques to optimally direct the high speed merge onto the expressway. It may be possible to utilize a Variable Message Sign (VMS) on the expressway just before the point where traffic merges to let current expressway drivers know that traffic is in the process of merging. This would be especially beneficial in

areas where there is inhibited visibility due to elevation shifts on ramps or obstruction of view due to bends in the roadway.

5.2 Intersection Control

Another fertile application area pertains to intersection control in cities. When intersections become crowded with traffic from special events, the street lights are ignored and a traffic safety officer moves in to manually direct traffic. The optimal signal timing for such an intersection could be a real time reactive scenario: video cameras monitor traffic coming into and going out of the intersection and the camera controls the signal lights to keep traffic moving in an optimal fashion. The visual sensor would have the ability to adjust the signal timing patterns in real time based on the throughput required for the increased traffic volume. Continuing on this thought process, each of the video sensor controlled intersections could be networked together with a central controller adjusting overall grid timing algorithms, in real time, to distribute the traffic influx across a wider area of the city, thereby easing the overall flow in any particular area.

5.3 Portable TFVC

Another interesting application for video sensor technology involves a portable configuration of the TFVC system. Given that some operational capability can be provided with any communications media, it is conceivable that cellular connectivity would make this system easy to set up in short order almost anywhere that cellular coverage exists. This characteristic of portability now allows the TFVC system to be "strapped" onto a pole wherever there is a need for automatic detection and

surveillance. With the large amount of construction that occurs on roadways, an automatic detection and control system directly connected to a VMS sign would alert drivers to difficult traffic situations ahead. The TFVC system would also give the traffic engineers at a central control facility immediate visibility into the traffic flow at any given road construction sight (via cellular link). With this information, the traffic engineer will have a better understanding of how the construction project affects the overall flow of vehicles across his particular area of interest.

5.4 Multi-Sensor Applications

With the rapid progression of the state-of-the-art in sensor technology, mechanical sensors have the capability to detect anomalies in a visual scenario better than the human eye. By incorporating a multi-sensor configuration, the overall robustness of the TFVC system can be greatly increased. Infrared cameras can be used to identify objects obscured by adverse weather conditions and detect heat radiating from individual occupants of vehicles thereby allowing the sensor system to obtain occupancy information about highway traffic. Acoustic sensors may be beneficial to augment a visual detection system because the acoustic sensor has the ability to detect variances in sound patterns. This type of characteristic would be beneficial for finer grain classification of vehicle sounds such as the type of engine, type of tire (snow tire, studded, etc.), excessive noise from exhaust (sound pollution), emergency vehicles (sirens) and even the detection of screeching tires and metal crashing together (accidents). A third type of sensor that would be beneficial to augmenting a multi-sensor configuration would be an environmental pollution sensor. This sensor would have the capability to detect excessive levels of toxic

exhaust from vehicles traveling on a given roadway. The sensor would trigger an alarm to the traffic engineer and at the same time signal the video sensor to take a snapshot of the current highway scene. With all three types of sensors working in concert with some type of expert analysis system, it would be possible to obtain a more detailed understanding of the current conditions. The expert system could also provide a detailed solution scenario to rectify the traffic situation.

6.0 CONCLUSION

The benefits of the TFVC system are appealing to any global community where traffic incidents and congestion hinder travel. The surveillance and forecasting functions of this system make it a valuable tool by which highways can become safer and more efficient. The system can almost immediately detect accidents and critical situations, thereby allowing a faster response time for emergency assistance. This prompt attention will save lives by providing the needed help to assist the victims of traffic incidents. Delays caused by accidents will diminish as traffic is successfully re-routed around problem areas. The TFVC system will decrease congestion by monitoring the highway situation while giving guidance to motorists through the use of Variable Message Signs which relay information about current traffic conditions. This will reduce delays and curtail accidents, while also saving the driver from unnecessary frustration. The forecasting capability of the system allows the traffic control operator to predict when accidents may occur based on historical data and current highway conditions, further preventing accidents by warning drivers of the conditions and situation. The TFVC system also provides environmental benefits. Through the mitigation of congestion,

the emissions from idling traffic will be reduced, thereby improving the overall air quality. The decrease in idling cars also reduces energy consumption, a further benefit to the environment. The TFVC system is expandable to almost any number of sensors so it can be utilized in metropolitan areas as well as smaller, more dispersed urban environments. The system can be implemented wherever there is a need for improved traffic flow. In conclusion, the surveillance and monitoring capabilities of the TFVC system make it a globally attractive system. Increased public safety, more efficient travel, and a cleaner environment are a significant benefit to any society.

ACKNOWLEDGMENTS

The authors of this paper would like to extend their sincere appreciation to the United States Air Force/Rome Laboratory, Kaman Sciences Corporation, New York State Department of Transportation, and the Federal Highway Administration for their continuing support of the TFVC program.

REFERENCES

[1] R. Sorensen, "A Comparison of Software Development Methodologies," Crosstalk, January 1995.

[2] M. S. Deutsch, Software Verification and Validation--Realistic Project Approaches, Prentice Hall, Englewood Cliffs, New Jersey, 1982.

[3] "Iteration in the Software Process", Proceedings of the Third International Software Process Workshop, Computer Society Press, Breckenridge, Colorado, 1986.

[4] Ramamoorthy, C. V. and C. R. Vick, Handbook of Software Engineering, Van Nostrand and Reinhold Co., New York, New York, 1984.

★U.S. GOVERNMENT PRINTING OFFICE: 1996-710-126-20099

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